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(56) Documents Cited
GB 2224778 A
GB 2175920 A
JP 620020916 A
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(54) Abstract Title
Multi-layered sliding material of tin-copper

(57) A multi-layer sliding material comprising a bearing alloy layer (2) and a tin base overlayer (6) of tin-copper series provided thereon through an intermediate layer (3), the tin base overlayer comprising a plurality of layers (4, 5) having different copper content, among which the lowest layer (4) in contact with the intermediate layer (3) contains 5 to 20% by per cent of copper and has a thickness of 1 to 3 µm. This prevents reduction in the copper content in the surface layer of the overlayer due to diffusion of copper for a long time and can maintain a good anti-seizure property without losing the conformability. The intermediate layer can be of Nickel, Iron or Cobolt and of 0.5-3 µm thickness. The upper layer (5) can have 0.5 to 10% of copper. The alloy layer (2) can be a Copper or Aluminium base alloy. The upper layer (5) can have up to 5% of Zinc, Indium, Antimony or Silver.

FIG.1

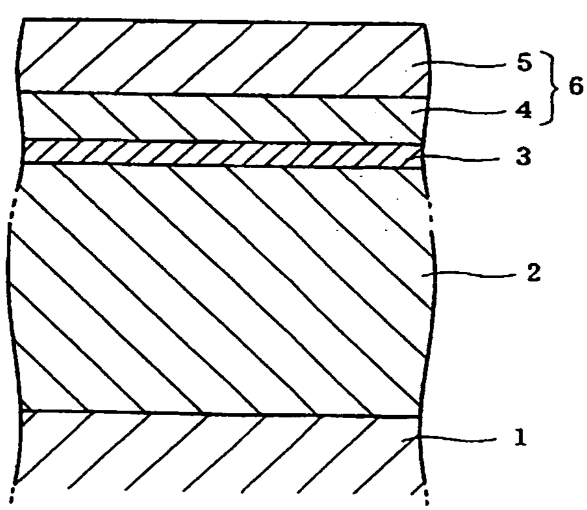

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FIG.1

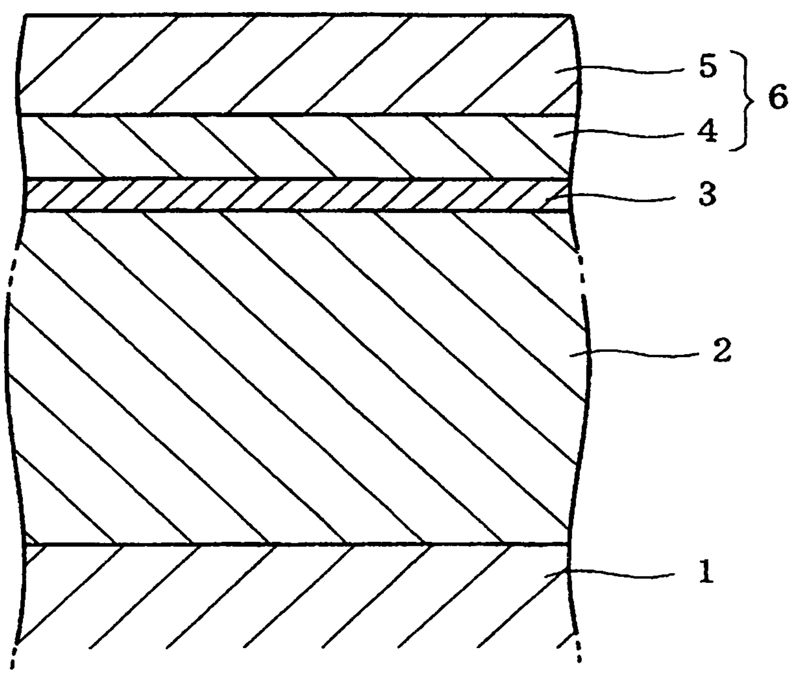

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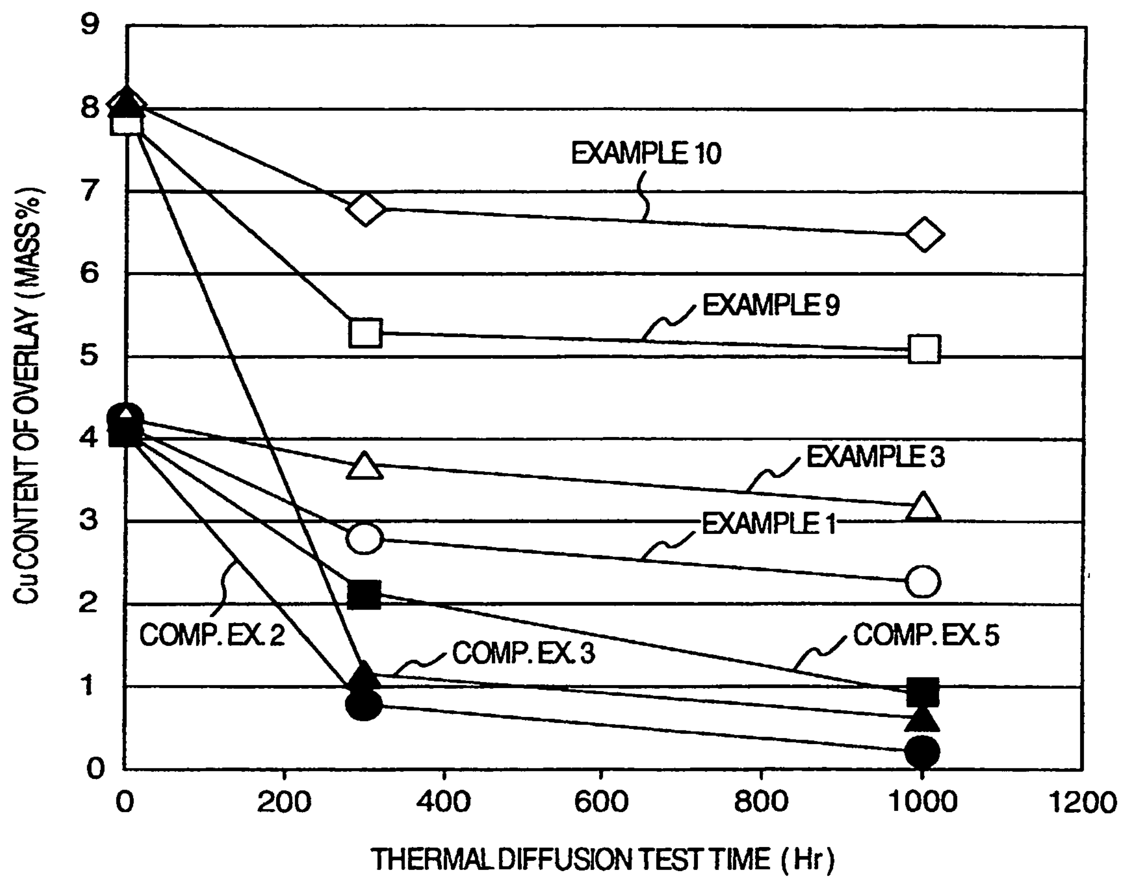
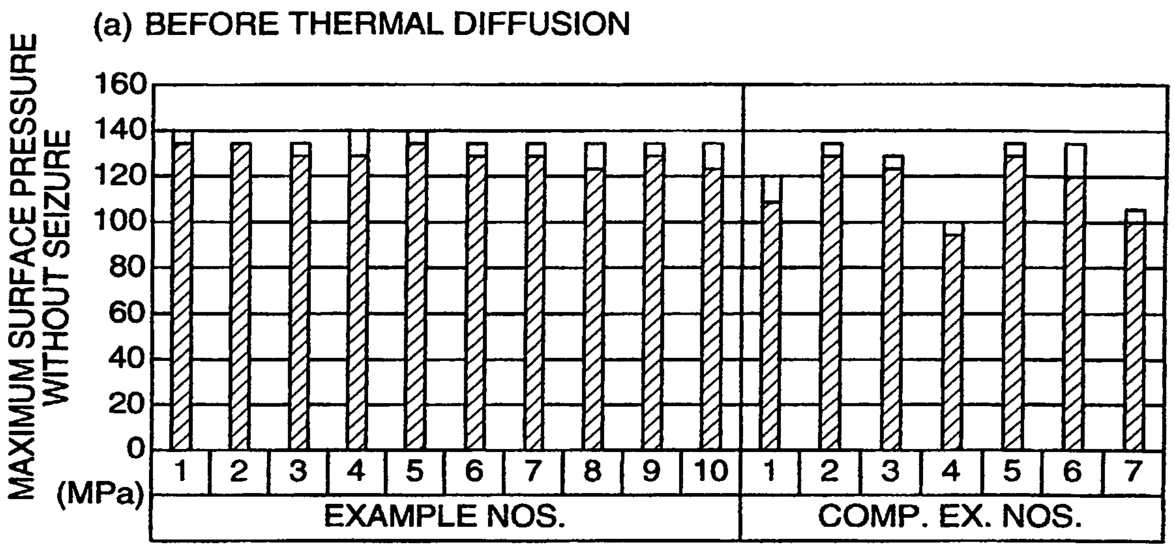
FIG.2



9
8
7
6
5
4
3
2
1
0
Cu CONTENT OF OVERLAY (MASS%)
0
200
400
600
800
1000
1200
THERMAL DIFFUSION TEST TIME (Hr)
EXAMPLE 10
EXAMPLE 9
EXAMPLE 3
EXAMPLE 1
COMP. EX. 2
COMP. EX. 3
COMP. EX. 5

FIG.3

SEIZURE TEST



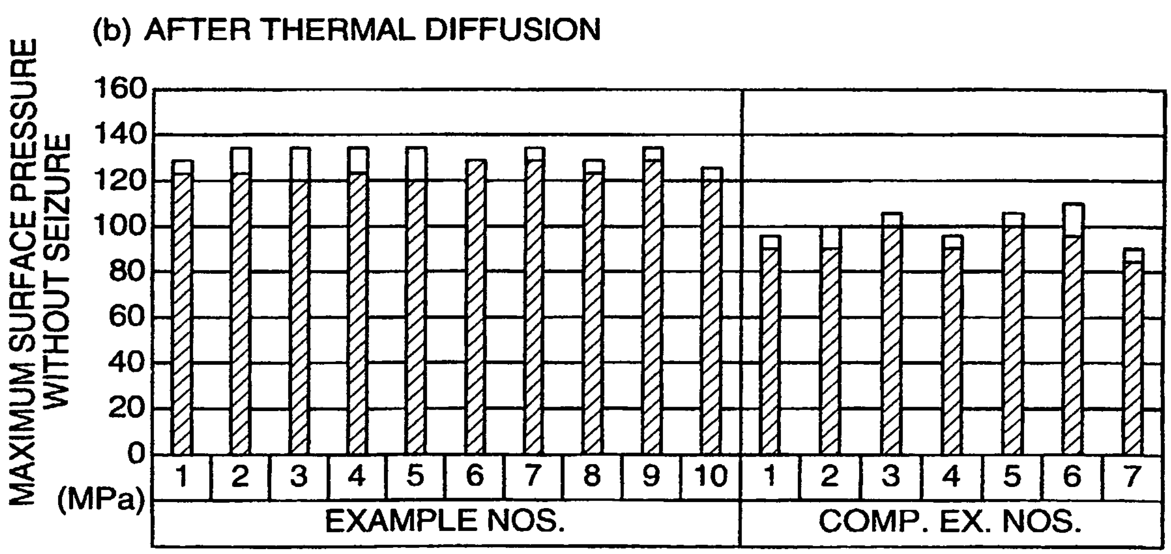
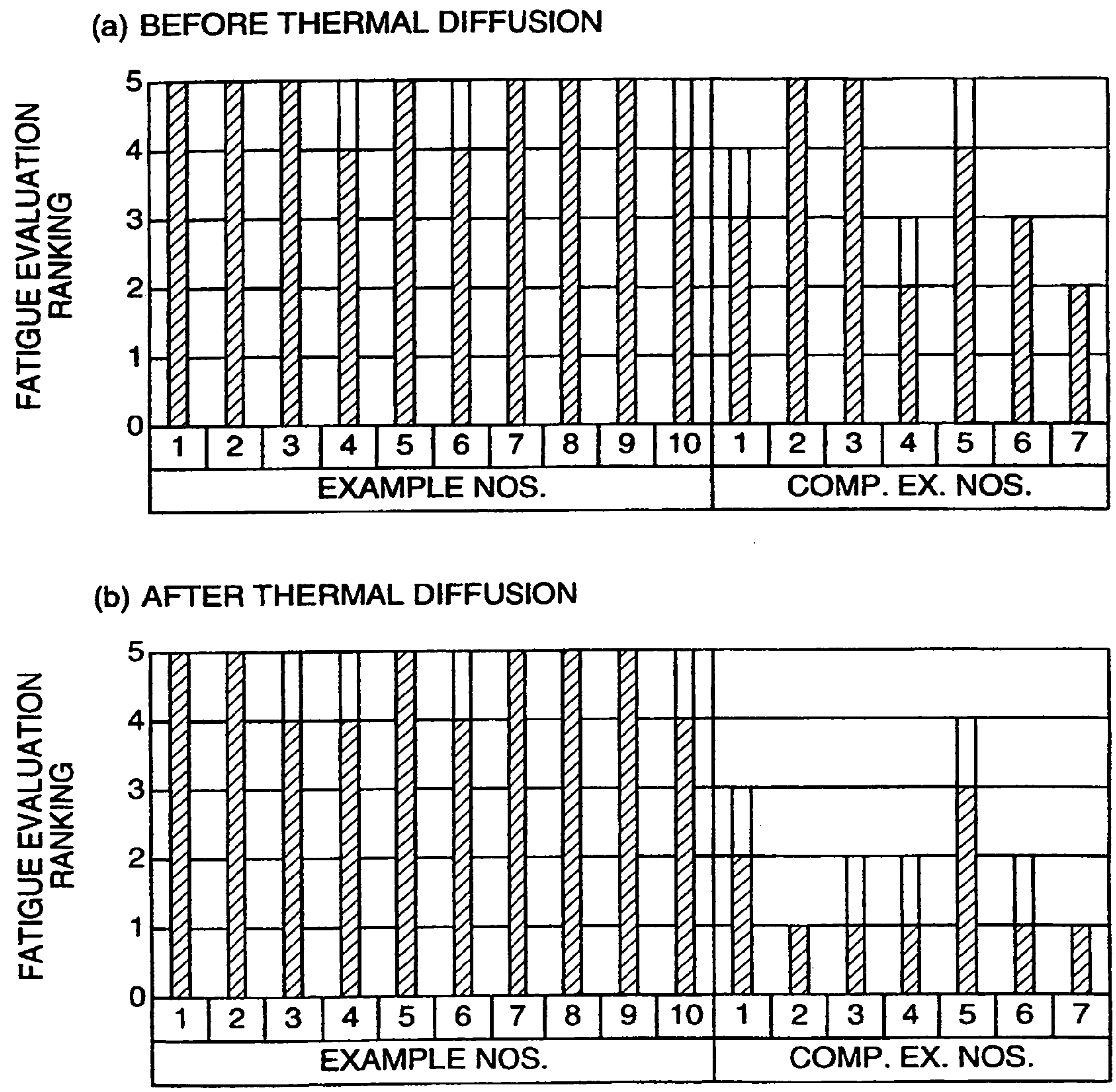


FIG.4

FATIGUE TEST



MULTI-LAYERED SLIDING MATERIAL

BACKGROUND OF THE INVENTION

The present invention relates to a multi-layered sliding material, which comprises a copper base or aluminum base bearing alloy layer and a tin base overlayer of tin-copper series provided thereon through an intermediate layer.

In the fields of automobiles, agricultural machinary and industrial machinary, plain bearings comprising a steel back metal and a copper base or aluminum base bearing alloy are often used. To improve the conformability or the foreign matter embeddability, an overlayer is often provided on the surface of the bearing alloy layer.

It is well known to use a lead base alloy as the overlayer, but to overcome the problem of global environment or improve the corrosion resistance, tin base alloys are nowadays often used. The plain bearing with the tin base overlayer is provided with, for example, a nickel plating layer as an intermediate layer between the bearing alloy layer and the overlayer. The nickel plating layer is provided to enhance the bondability of the tin base overlayer in case of an aluminum base bearing alloy, and to prevent diffusion of tin from the tin base overlayer into the bearing alloy.

However, in case the overlayer is composed of tin base alloy of tin-copper series, copper in the overlayer diffuses into the nickel plating layer under the thermal influence, when used at elevated temperatures for a long time, resulting in reduction in the copper content of the overlayer and consequent lowering of fatigue resistance and anti-seizure property. To prevent diffusion of the copper from the overlayer into the nickel plating layer, JP-A-2000-64085 discloses that the intermediate layer must be composed of a 1-3 μm thick nickel layer and a 2-10 μm thick nickel-tin layer deposited thereon.

In the structure of the intermediate layer disclosed in JP-A-2000-64085, the nickel layer as a lower layer is hard, and the nickel-tin layer as an upper layer is much harder. When the overlayer is worn out during the use for a considerably long time, the hard nickel-tin layer or nickel layer will be exposed to the surface. The nickel-tin layer or the nickel layer is considerably thick, for example, 3-13 μm in total, and is too hard to be worn out, resulting in worse conformability and a high possibility of seizure.

SUMMARY OF THE INVENTION

An object of the present invention is to improve the disadvantages of the prior art and to provide a multi-layered sliding material capable of preventing reduction in the copper content in the

surface layer of the tin base overlayer due to the diffusion of copper as much as possible without making larger the thickness of the intermediate layer formed between the tin base overlayer and the bearing alloy.

The present invention provides a multi-layered sliding material, which comprises a bearing alloy layer and a tin base overlayer of tin-copper series provided thereon through an intermediate layer, the tin base overlayer comprising a plurality of layers having different copper contents, among which the lowest layer in contact with the intermediate layer contains 5 to 20% by mass of copper and has a thickness of 1 to 3 μm.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional view of a multi-layer sliding material according to an embodiment of the present invention.

Fig. 2 is a graph showing results of thermal diffusion tests.

Fig. 3 is a graph showing results of seizure tests.

Fig. 4 is a graph showing results of fatigue tests.

DETAILED DESCRIPTION OF THE INVENTION

The present multi-layered sliding material comprises a bearing alloy layer and a tin base

overlayer of tin-copper series provided thereon through an intermediate layer, the tin base overlayer comprising a plurality of layers having different copper contents, among which the lowest layer in contact with the intermediate layer contains 5 to 20 by mass of copper and has a thickness of 1 to 3 μm.

The bearing alloy layer can be composed of ordinary copper base alloy or aluminum base alloy. The copper base or aluminum base bearing alloy has distinguished bearing properties under high loads and at high speed revolutions and thus is particularly suitable for plain bearings for engines in the fields of automobiles, agricultural machinary and industrial machinary. Any of bronze base and lead bronze base alloys can be used as the copper base alloy. As the aluminum base alloy, those containing at least one of zinc, tin, lead, etc. to form a soft phase can be used, and copper, magnesium, etc. can be also contained as reinforcing elements and chromium, silicon, etc. can be also used to improve the fatigue resistance.

Between the copper base or aluminum base bearing alloy layer and the tin base overlayer of tin-copper series an intermediate layer is provided to prevent diffusion of tin from the tin base overlayer into the bearing alloy layer or improve the bondability of the tin base overlayer to the bearing alloy layer. The intermediate layer can be composed of any one of nickel, iron and cobalt, and the thickness is prefer-

ably 0.5 to 3 μm.

When the sliding material is used at elevated temperatures, copper diffuses from the tin base over-layer into the intermediate layer. According to the present invention, the lowest layer of the tin base overlayer has a relatively high copper content, and thus diffusion of copper from the tin base overlayer into the intermediate layer starts from the lowest layer of the tin base overlayer. That is, reduction in the copper content of the uppermost layer of the tin base overlayer in contact with the counter member is less. The intermediate layer can be made not so thick and can maintain a distinguished anti-seizure property without losing the conformability, even if the tin base overlayer is worn out to expose the intermediate layer to the surface.

The copper content in the uppermost layer of the tin base overlayer is preferably 0.5 to 10% by mass.

The uppermost layer of the tin base overlayer can contain not more than 5% by mass of at least one of zinc, indium, antimony and silver in sum total.

Reasons why the aforementioned proportions and thicknesses are selected will be as follows:

(1) Copper content in the lowest layer of the tin base overlayer: 5 to 20% by mass.

Below 5% by mass of copper, the prevention of copper diffusion from the uppermost layer of the tin

base overlayer tends to be less effective, whereas above 20% by weight of copper the fatigue resistance tends to be lowered.

Thickness of the lowest layer of the tin base overlayer is 1 to 3 μm. Below 1 μm, prevention of copper diffusion from the uppermost layer tends to be less effective, whereas above 3 μm the fatigue resistance tends to be lowered.

(2) Copper content in the uppermost layer of the tin base overlayer: preferably 0.5 to 10% by mass.

Tin matrix plays an important role in corrosion resistance, conformability and foreign matter embeddability, and copper can enhance the strength of the tin matrix and improve the anti-seizure property, fatigue resistance and wear resistance. Below 0.5% by mass, copper tends to be less effective, whereas above 10% by mass the anti-seizure property and fatigue resistance tend to be lowered.

Thickness of the uppermost layer of the tin base overlayer is preferably 10 to 40 μm. Below 10 μm the conformability and foreign matter embeddability tend to be lowered, whereas above 40 μm the fatigue resistance tends to be lowered.

(3) Contents of at least one of zinc, indium, antimony and silver in the uppermost layer of the tin base overlayer: preferably not more than 5% by mass in sum total.

These elements can improve the anti-seizure

property and wear resistance of the uppermost layer of the tin base overlayer. Above 5% by mass the uppermost layer tends to be too hard, and the conformability and foreign matter embeddability tend to be lowered.

(4) Intermediate layer: preferably any of nickel, iron and cobalt.

Nickel, iron and cobalt can prevent diffusion of tin from the tin base overlayer into the bearing alloy layer in case of copper base bearing alloy or enhance the bondability of the tin base overlayer to the bearing alloy layer in case of aluminum base bearing alloy.

Thickness of the intermediate layer is preferably 0.5 to 3 μm. Below 0.5 μm, neither good dam effect nor good bondability will be obtained, whereas above 3 μm the anti-seizure property after the tin base overlayer is worn out tends to be lowered.

The present invention will be described below, referring to Examples and Drawings.

Examples 1 to 10 and Comparative Examples 1 to 7

Bimetal was made as a bearing material by sintering and rolling a copper base bearing alloy comprising 23% by mass of lead and 3.5% by mass of tin, the balance being copper, onto a steel plate. The resulting bimetal was press formed into a 1.5 mm-thick half bearing, which was further machined to desired dimensions. Then, a 1.5 μm-thick nickel layer was formed on the inner surface of the half bearing by

electroplating and thereafter a tin bese alloy comprising components as shown in Table 1 as Lower Layer was electroplated onto the nickel layer except Comparative Examples Nos. 1 to 4, and a tin base alloy comprising components as shown in Table 1 as Upper Layer was further electroplated onto the lower layer. As to Comparative Examples Nos. 1 to 4, the tin base alloy comprising components as shown in Table 1 as Upper layer was electroplated to a thickness of 15 μm onto the nickel layer only as a single layer.

In Example Nos. 1 to 10 and Comparative Example Nos. 5 to 7, test pieces in structures each comprising back steel layer 1, copper base bearing alloy layer 2 formed on said back steel layer 1, intermediate layer 3 consisting of a nickel plating layer formed on said bearing alloy layer 2 and tin base overlayer 6 consisting of two layrs, i.e. lower layer 4 and upper layer 5 having different copper contents formed on said intermediate layer 3, as shown in Fig. 1 were obtained by the aforementioned procedure. In Comparative Examples Nos. 1 to 4, test pieces in structures comprising a back steel layer, a copper base bearing alloy layer formed on said back steel layer and a single tin base overlayer formed on the bearing alloy layer through an intermediate layer consisting of a nickel plating layer, though not shown in the drawing, were obtained.

Table 1

Test piece		Tin base overlayer								
		Upper layer						Lower layer		
Classification	No.	Component (mass %)					Thickness µm	Component (mass %)		Thickness µm
		Sn	Cu	In	Ag	Sb		Sn	Cu	
Example	1	Balance	4.2				15	Balance	5.2	1
	2	"	4.1				15	"	10.1	1
	3	"	4.3			3.1	15	"	19.1	1
	4	"	4.2				15	"	9.8	2
	5	"	3.9		2.0		15	"	19.5	2
	6	"	8.1				15	"	5.1	2
	7	"	8.2				15	"	9.9	2
	8	"	7.9	2.1			15	"	19.8	2
	9	"	7.9				15	"	5.2	3
	10	"	8.1				15	"	19.7	3
Comparative Example	1	"	0.3				15	–	–	–
	2	"	4.1				15	–	–	–
	3	"	8.1				15	–	–	–
	4	"	13.1				15	–	–	–
	5	"	4.1				15	Balance	10.1	0.5
	6	"	4.2				15	"	10.2	5
	7	"	3.9				15	"	23.5	2

Test pieces of Examples Nos. 1 to 10 and Comparative Examples Nos. 1 to 7 were subjected to a thermal diffusion test, a seizure test and a fatigue test.

Thermal diffusion test was carried out to investigate copper content in the upper layer of the tin base overlayer each after keeping the heated state

at 130°C for 300 hours and after keeping that state for 1,000 hours.

Seizure test was carried out by using a preheated lubricating oil of VG22 at 100°C, rotating the counter member at 3,600 rpm by a motor and giving a load under surface pressure at 10 MPa thereto by reducing a flow rate of the lubricating oil to 150 cc/min. after a running-in under no load for one hour, then increasing the surface pressure 5 MPa by 5 MPa, while running under each surface pressure for 10 minutes to determine the bearing surface pressure when the temperature of the bearing back exceeded 200°C or the driving current of the motor for driving the counter member exceeded the predetermined value as a seizure surface pressure. The seizure test was carried out twice each for test pieces not subjected to said thermal diffusion and for those subjected to thermal diffusion at 130°C for 1,000 hours.

Fatigue test was carried out by using a preheated lubricating oil of SAE20 at 100°C, rotating the counter member at 3250 rpm and giving a load under surface pressure of 50 MPa thereto to run for 20 hours after a running-in under no load for 30 minutes, thereby evaluating a degree of fatigue. Evaluation is given by the following 5 classes of fatigue evaluation ranking. As in the seizure test, the fatigue test was carried out twice each for test pieces not subjected to thermal diffusion and for those subjected to thermal

diffusion at 130°C for 1,000 hours.

5 : No cracking is observed at all.

4 : Cracking is observed not visually, but microscopically.

3 : Cracking is visually observable, but not discriminately.

2 : Cracking is visually observable.

1 : Not less than 50% of cracking is visually observable in terms of bearing projection area.

Results of the thermal diffusion test of Examples Nos. 1, 3, 9 and 10 and Comparative Examples Nos. 2, 3 and 5 are graphically shown in Fig. 2. Results of the seizure test and fatigue test thereof are also graphically shown in Fig. 3 and Fig. 4, respectively, where unhatched portions each at the tops in histogramic columns show deviations each in the two test results.

As is apparent from Figs. 2 to 4, the copper content of the surface layer of the tin base overlayer is less reduced by thermal diffusion of copper in Examples Nos. 1 to 10 embodying the tin base overlayer consisting of two layers, i.e. an upper layer and a lower layer, where the lower layer contains 5 to 20% by mass of copper than that in Comparative Examples Nos. 1 to 4 showing the absence of a lower layer. That is, Examples Nos. 1 to 10 show distinguished anti-seizure property and fatigue resistance even after the thermal

diffusion test at 130°C for 1,000 hours.

Comparative Examples Nos. 5 to 7 show a tin base overlayer consisting of two layers, i.e. an upper layer and a lower layer. Comparative Example 7 shows a low fatigue resistance, because the copper content in the lower layer of the tin base overlayer is as high as 23.5% by mass before the thermal diffusion test. When the copper content in the lower layer of the tin base overlayer is lower, the effect on prevention of the upper layer from copper diffusion is lowered, whereas when higher an adverse effect on the fatigue resistance is produced. Thus, the copper content in the lower layer of the tin base overlayer is preferably 5 to 20% by mass.

Comparative Example No. 5 shows that the lower layer of the tin base overlayer is as thin as 0.5 μm, so that the effect on prevention of the upper layer from copper diffusion is lower. That is, the copper content in the upper layer was initially 4.1% by weight, but was considerably reduced to, for example, 2.1% by mass after the thermal diffusion test for 300 hours and 0.9% by mass after the thermal diffusion test for 1,000 hours. As a result, the anti-seizure property and the fatigue resistance were lowered after the thermal diffusion test for 1,000 hours. Comparative Example No. 6, on the other hand, shows that the lower layer of the tin base overlayer is as thick as 5 μm, the fatigue resistance is poor even before the

thermal diffusion test. It can be seen from the foregoing facts that when the lower layer of the tin base overlayer has a smaller thickness, the effect on prevention of the upper layer from copper diffusion will be lowered, whereas when it has a larger thickness, the fatigue resistance will be lowered. Thus, the thickness of the lower layer of the tin base overlayer is preferably 1 to 3 μm.

Reduction in the copper content of the upper layer can be suppressed by making the tin base overlayer consist of two layers, i.e. an upper layer and a lower layer, and also making the lower layer have a copper content of 5 to 20% by mass and a thickness of 1 to 3 μm, and as a result the thickness of the nickel plating layer as an intermediate layer can be made smaller (e.g. 1.5 μm in Examples Nos. 1 to 10). Thus, when the overlayer is worn out to expose the intermediate layer to the surface, the intermediate layer will be worn out for a relatively short time, thereby reducing chances of seizure due to contact of the counter member with the hard nickel intermediate layer.

The foregoing Examples and those as shown in the drawings should not be construed to be restrictive of the present invention, and the present invention should be construed to include the following modification and alterations.

The intermediate layer is made not only of nickel, but also of iron or cobalt.

The copper content in upper layer 5 of tin base overlayer 6 may be higher than that in lower layer 4.

Tin base overlayer 6 may consist not only of two layers but also of three or more layers. In that case, it is preferable that the copper content is made lower in the direction from the lowest layer towards the uppermost layer, but so long as the copper content of the lowest layer is 5 to 20% by mass, the copper content of upper layers above the lowest layer may be higher or lower.

The uppermost layer of the tin base overlayer may contain not more than 5% by mass of inorganic particles to improve the wear resistance.

WHAT IS CLAIMED IS:

1. A multi-layered sliding material, which comprises a bearing alloy layer and a tin base overlayer of tin-copper series provided thereon through an intermediate layer, the tin base overlayer comprising a plurality of layers having different copper contents, among which the lowest layer in contact with the intermediate layer contains 5 to 20% by mass of copper and has a thickness of 1 to 3 μm.

2. A multi-layered sliding material according to Claim 1, wherein the copper content in the uppermost layer of the tin base overlayer is 0.5 to 10% by mass.

3. A multi-layered sliding material according to Claim 1 or 2, wherein the uppermost layr of the tin base overlayer contains not more than 5% by mass of at least one of zinc, indium, antimony and silver.

4. A multi-layered sliding material according to any one of Claims 1 to 3, wherein the intermediate layer is composed of any one of nickel, iron and cobalt, and has a thickness of 0.5 to 3 μm.

5. A multi-layered sliding material according to any one of Claims 1 to 4, wherein the bearing alloy layer is composed of a copper base alloy or an aluminum base alloy.

6. A multi-layered sliding material substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

The Patent Office

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Application No:	GB 0206056.4	**Examiner:**	Dave McMunn
Claims searched:	1-6	**Date of search:**	17 September 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): F2A (AD38, AD44).

Int.Cl (Ed.7): F16C 33/12.

Other: ONLINE : WPI, EPODOC, JAPIO.

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2,224,778 A	(METAL LEVE). Note layers	1
A	GB 2,201,690 A	(DAIDO).Note layers	1
A	GB 2,175,920 A	(GLYCO-METAL). See figs 3 & 4	1
A	GB 1,463,474	(MIBA). Note layers	1
X	JP 62020916	(NDC). See figs & English abstract	1,2,4,5

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		